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(54) **IMPACT ENHANCING APPARATUS AND METHOD**

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E21B 10/38 (2006.01)

(52) **U.S. Cl.** **175/57**; 175/296; 166/301

(58) **Field of Classification Search** .... None
See application file for complete search history.

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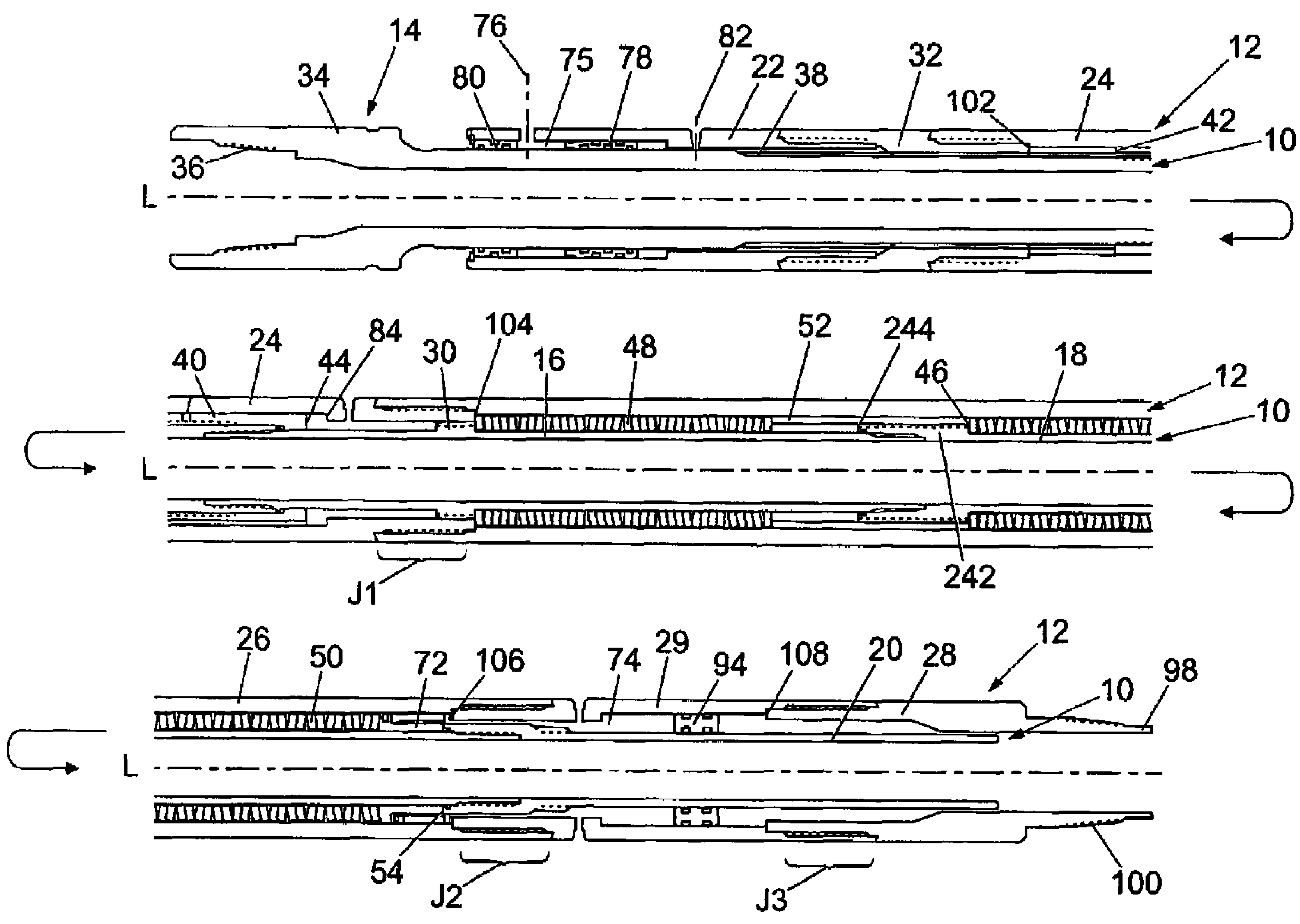
(57) **ABSTRACT**

An impact enhancer apparatus includes: a substantially tubular inner member, a substantially tubular outer member that is axially movable in relation to the inner member, a primary energy storage device adapted to store energy when the inner member is moved in either of first and second axial directions with respect to the outer member and a secondary energy storage device adapted to store energy when the inner member is moved in a first axial direction with respect to the outer member. The primary energy storage device may include a primary biasing device. The secondary energy storage device may include a secondary biasing device. The primary and/or secondary biasing devices may be a spring device such as a disk spring, a coiled spring, a fluid spring, a gas spring, etc. The impact enhancing devices may include tubular members that have double shoulder high torque connections.

19 Claims, 4 Drawing Sheets



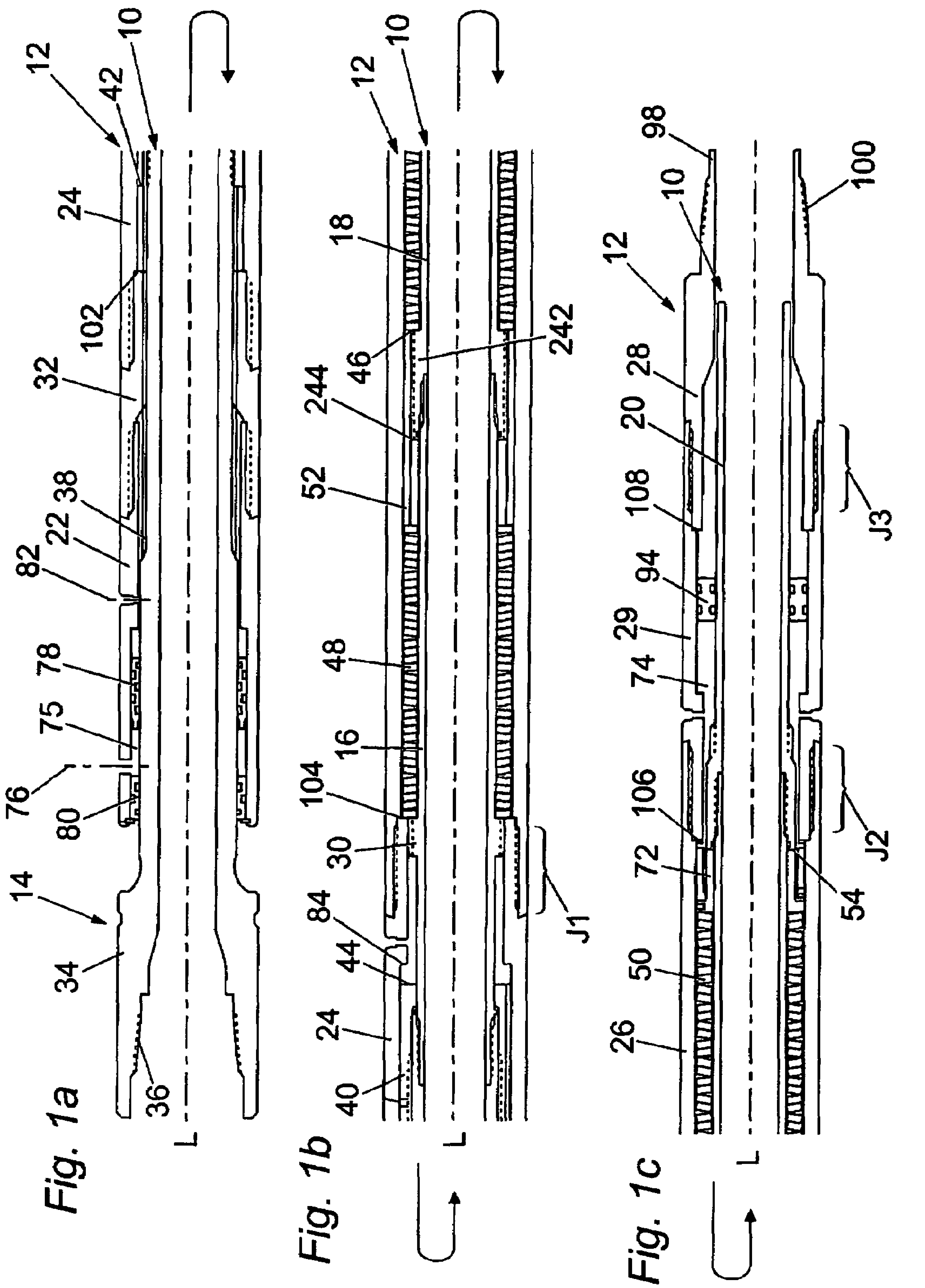


Fig. 1a

Fig. 1b

Fig. 1c

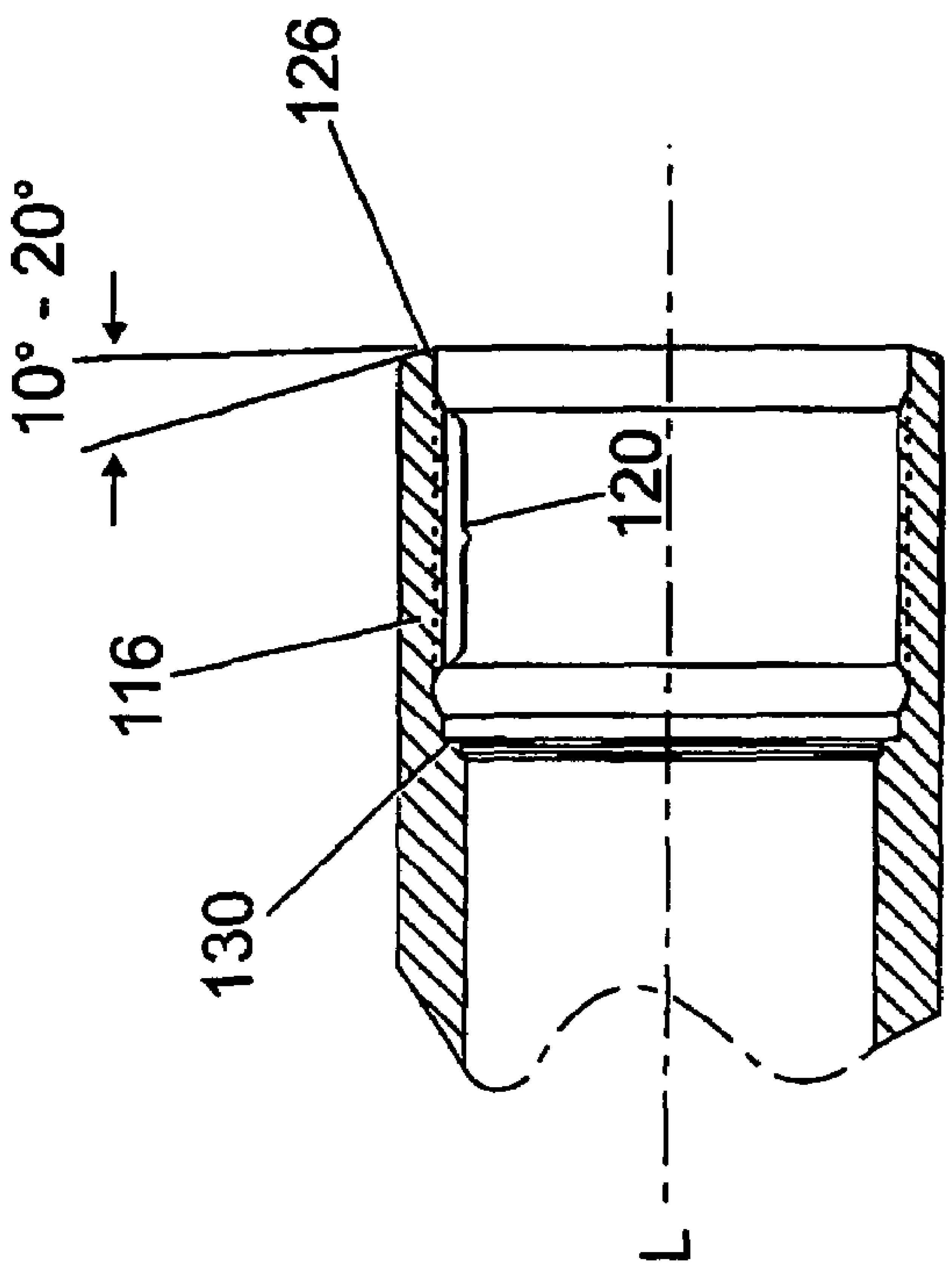


Fig. 2a

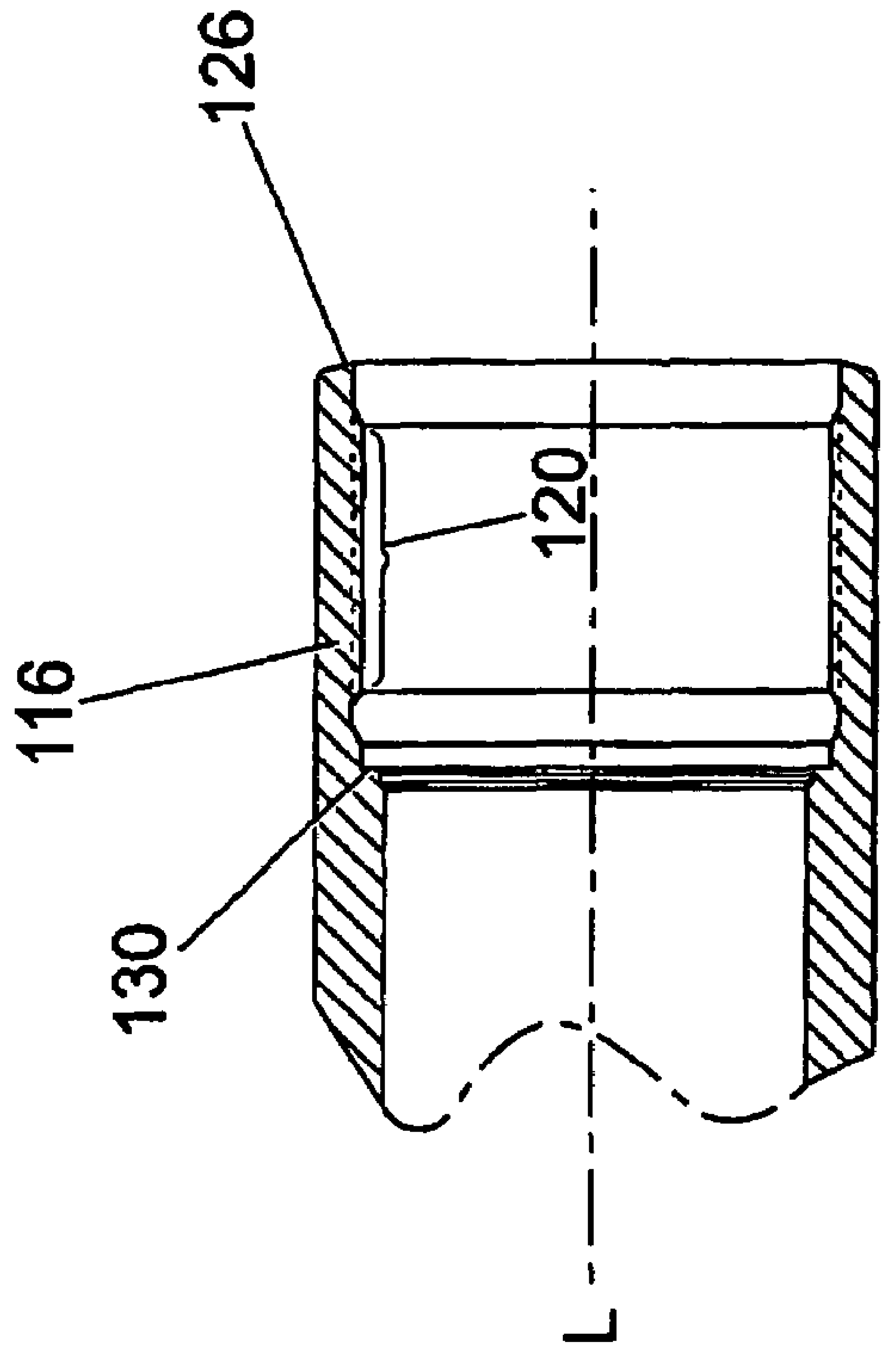


Fig. 2b

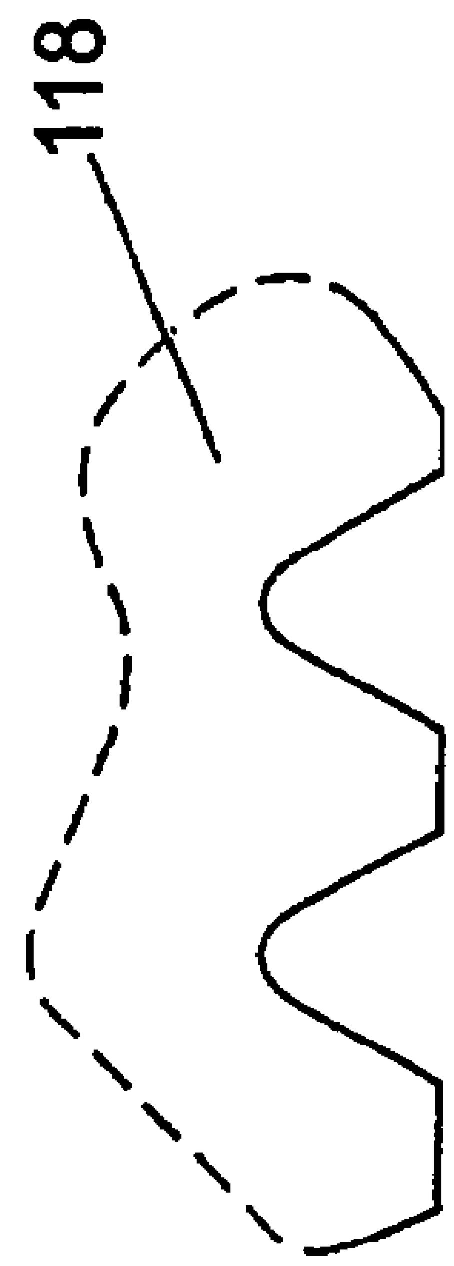


Fig. 2c

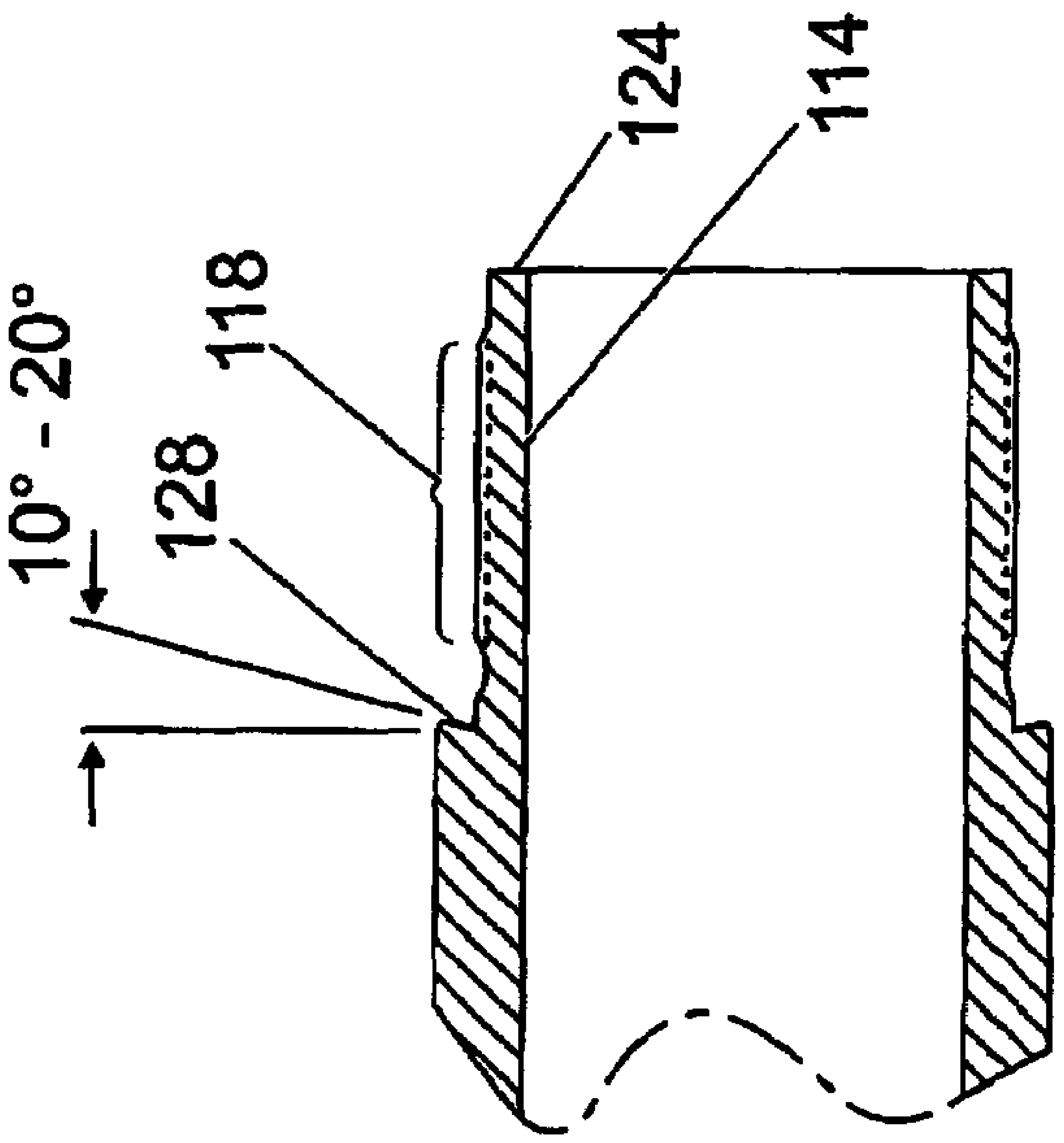


Fig. 3b

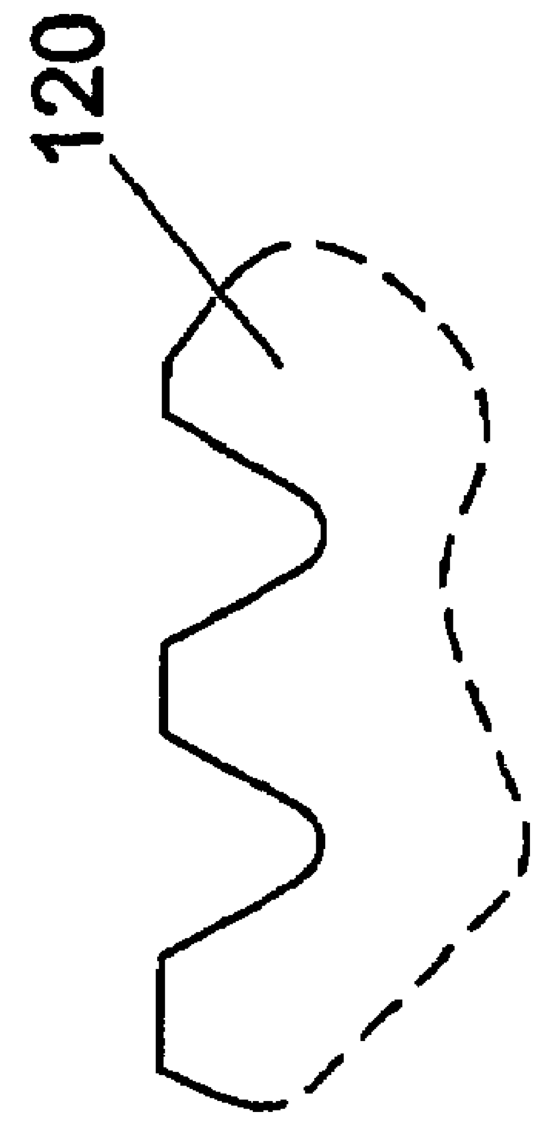


Fig. 3c

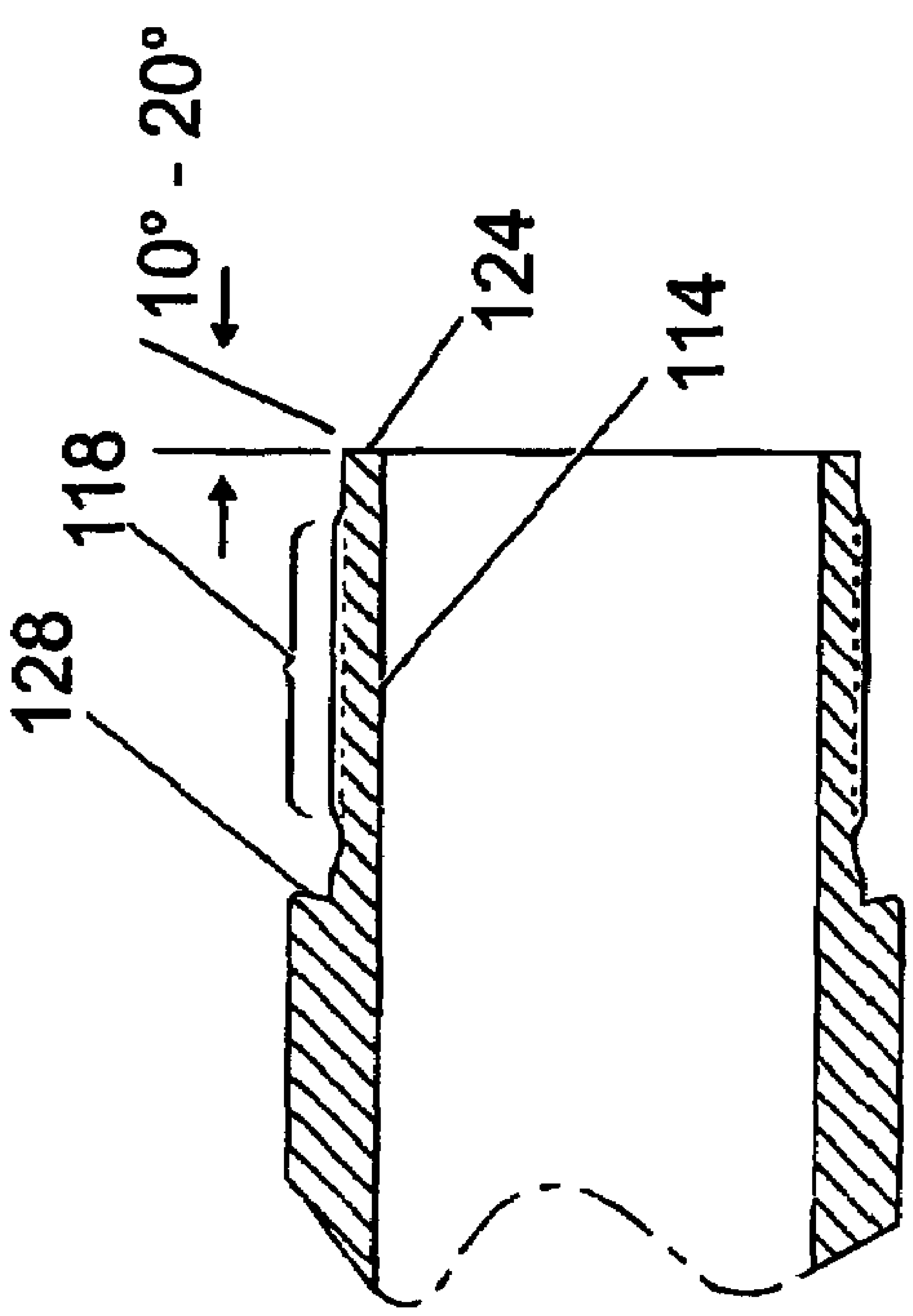


Fig. 3a

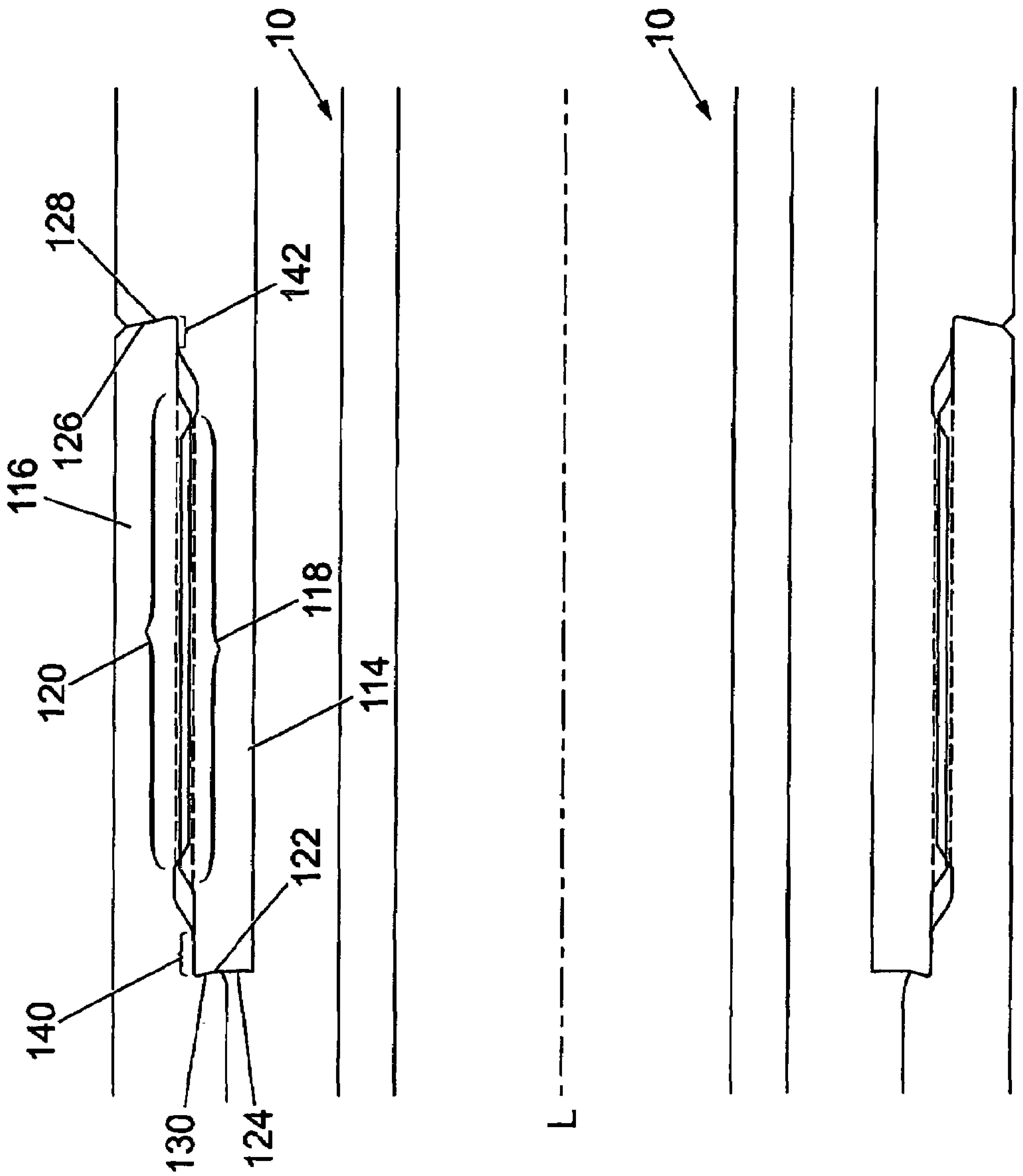


Fig. 4

IMPACT ENHANCING APPARATUS AND METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to GB 0413996.0, which was filed on Jun. 23, 2004 and which is incorporated by reference herein in its entirety.

BACKGROUND

The present invention relates to a method and an apparatus for enhancing the impact created by a drilling jar used downhole when the drill string becomes stuck.

Drilling jars are used widely in the drilling industry to allow a jarring impact to be transmitted to the drill string when, for example, the drill string becomes stuck in the borehole in which the drilling operation is being performed.

Drilling jars may be incorporated into a bottom hole assembly of a drill string and comprise an outer tubular housing which surrounds an inner tubular member. The outer tubular housing may be connected at its lower end to the lower portion of the drill string while the upper end of the inner tubular member is connected to the upper portion of the drill string. The inner member and outer housing are telescopically connected such that one may move axially with respect to the other. Generally, the inner member of a drilling jar has an abutment that acts as a hammer and coincides with an internal shoulder provided on the outer housing of the jar that acts as an anvil such that the free stroke of the inner member with respect to the outer housing causes the hammer to impact against the anvil. This impact causes the lower drill string portion to jar.

The impact momentum (also referred to as "impact force") created by the jar is the speed of the hammer multiplied by the hammer weight at the time of impact, where the hammer weight is the weight of any drill collars and/or heavy weight pipe located between the jar hammer and drill pipe or energizer.

The impact force between the hammer and anvil may be increased using an impact enhancing tool that employs energy storage means that can be used to store energy, which when suddenly released causes the inner member of the jar to accelerate with respect to the outer housing of the jar, while the hammer is moving toward the anvil.

Unfortunately, in conventional drilling strings, the pins and boxes are subject to stretching both when the tubular members are connected and during drilling.

What is needed, therefore, is an apparatus and a methodology that address at least one if not more of the deficiencies that afflict conventional practice, as previously described.

SUMMARY

According to a first embodiment of the present invention, there is provided an impact enhancer apparatus that includes, among other possible things: a substantially tubular inner member; a substantially tubular outer member which is axially movable in relation to the inner member; a primary energy storage means adapted to store energy when the inner member is moved in either of first and second axial directions with respect to the outer member; and a secondary energy storage means adapted to store energy when the inner member is moved in a first axial direction with respect to the outer member.

The primary energy storage means may include a primary resilient means which may comprise a primary biasing means which may be any one of a spring means (such as disk springs, coiled springs, fluid or gas springs, etc.). The secondary energy storage means may include a secondary resilient means which may comprise a secondary biasing means which may be any one of a spring means (such as disk springs, coiled springs, fluid or gas springs, etc.).

The primary energy storage means may be adapted to store energy when compressed by movement of the inner member in either of the first and second axial direction with respect to the outer member.

The secondary energy storage means may be adapted to store energy when compressed by movement of the inner member in the first axial direction with respect to the outer member.

The primary and secondary energy storage means may be adapted to resist movement (and thereby store energy) of the inner member in the upward direction with respect to the outer member with a relatively large resistive force. Moreover, the primary energy storage means may be adapted to resist movement (and thereby store energy) of the inner member in the downward direction with respect to the outer member with a relatively weak resistive force. Further, only the primary energy storage means may be adapted to resist movement (and thereby store energy) of the inner member in the downward direction with respect to the outer member with a relatively weak resistive force.

The primary energy storage means may be adapted to resist upward movement of the inner member with respect to the outer member by a first resilient force when the inner member is displaced to an upward displacement boundary and the secondary energy storage means is adapted to resist upward movement of the inner member with respect to the outer member by a second resilient force when the inner member is displaced past the upward displacement boundary.

The primary and secondary energy storage means may include a plurality of resilient disks. Alternatively, the primary and secondary energy storage means comprise any suitable resilient member such as a coiled spring or the like.

The primary energy storage means may be adapted to provide a lower level of resistive force to compression than that provided by the secondary energy storage means.

The difference in the level of resistive force provided by the energy storage means may be determined due to the orientation of the energy storage means which selectively results in a greater or lesser compression displacement when substantially the same force is placed upon the energy storage means.

The primary energy storage means may include a plurality of spring disks (such as two) oriented in the same direction as one another. The plurality of disks in the primary resilient means may be arranged with two disks oriented in one direction alternating with two disks oriented in the other direction.

The secondary energy storage means may include a plurality of spring disks (such as four) oriented in the same direction as one another. The plurality of disks in the secondary energy storage means may be arranged with a greater number (such as twice the number) of disks of the primary energy storage means oriented in one direction alternating with the same greater number of spring disks oriented in the other direction.

Movement of the inner member in the upward direction may cause the primary and secondary energy storage means to be compressed until the upward displacement limit is reached at which point further upward movement of the inner member only causes the secondary energy storage means to be compressed further.

Movement of the inner member in the downward direction may cause only the primary energy storage means to be compressed, the secondary energy storage means may be allowed to move with the inner member without being compressed.

The energy storage means may be located in an annulus formed between the inner and outer members.

The primary energy storage means may be located within the annulus and are further located between a second arrangement of upper and lower shoulders formed on the inner member and may be further located between a lower shoulder formed on the outer member and a lower shoulder formed on the moveable member.

The secondary energy storage means may be located within the annulus and are further located between a first arrangement of upper and lower shoulders formed on the inner member and may be further located between an upper shoulder formed on the outer member and an upper shoulder formed on a moveable member that may also be located in the annulus.

The moveable member may be located in the annulus between the primary and secondary energy storage means and may include a greater axial extent and thus a greater distance between it's upper and lower shoulders than the distance between the inner member lower shoulder of the first arrangement and the inner member upper shoulder of the second arrangement.

The impact enhancing apparatus may be arranged such that, in the absence of compression to the energy storage means, the distance between the upper shoulder of the first arrangement and the upper shoulder of the second arrangement substantially equals the distance between the upper shoulder of the outer member and the lower shoulder of the moveable member.

According to the another embodiment of the present invention, there is also provided a method of increasing the jarring force imparted by a jar apparatus. This method includes, among other possible steps: providing a substantially tubular inner member; providing a substantially tubular outer member; and providing an energy storage means capable of storing greater energy therein due to upward movement of the inner member with respect to the outer member.

According to a second embodiment of the present invention, there is provided connection means adapted to allow connection of one substantially tubular member to another substantially tubular member. The connection means includes, among other possible things: a male connecting member; a female connecting member; and co-operable attachment means provided on the male and female connecting members. The male and female connecting members each comprise at least one primary surface adapted to form a primary joint and further each comprise at least one secondary surface adapted to form a secondary joint.

According to the second embodiment of the present invention, there is also provided a male connecting member for a substantially tubular member which is arranged for connection to a female connecting member of another substantially tubular member. The male connecting member includes, among other possible things: an attachment means co-operable with an attachment means provided on the female connecting member; at least one primary surface adapted to form a primary joint with at least one primary surface provided on the female member; and at least one secondary surface adapted to form a secondary joint with at least one secondary surface provided on the female member.

According to the second embodiment of the present invention, there is also provided a female connecting member for a substantially tubular member which is arranged for connection to a male connecting member of another substantially tubular member. The female connecting member includes, among other possible things: an attachment means co-operable with an attachment means provided on the male connecting member; at least one primary surface adapted to form a primary joint with at least one primary surface provided on the male member; and at least one secondary surface adapted to form a secondary joint with at least one secondary surface provided on the male member.

The tubular member may connect with another tubular member in accordance with the first embodiment of the present invention to form at least part of the outer housing of a downhole tool for incorporation into a string of downhole tubular members such as drill string.

An end the male member may be adapted for insertion into an end of the female member.

The at least one primary surface may be adapted to form a primary load bearing shoulder joint and moreover, the at least one secondary surface may be adapted to form a secondary load bearing shoulder joint. The primary and secondary joints may be formed between the male and female connecting members when the male and female connecting members are connected to one another.

The co-operable attachment means of the male and female connecting members may retain the primary surface of the male connecting member in abutment with the primary surface of the female connecting member.

The co-operable attachment means of the male and female connecting members may retain the secondary surface of the male connecting member in abutment with the secondary surface of the female connecting member.

The co-operable attachment means of the male and female connecting members may retain the primary and secondary surfaces of the male connecting member in abutment with the respective primary and secondary surfaces of the female connecting member, perhaps in order to create the respective primary and secondary joints between the male and female members. Moreover, at least one of the primary and secondary joints may at least partially resist rotation of one of the connecting members with respect to the other in at least one direction.

This has the advantage that embodiments of the invention provide a pair of butting surfaces (between each pair of primary and secondary surfaces) between the male and female members which resist rotation of the members with respect to one another.

The attachment means may include a thread on the male member which is co-operable with a corresponding thread on the female member. Moreover, the thread may force the or each primary and/or secondary surface of the connecting members into abutment with the corresponding surface of the other connecting member. The thread provided on the male and female members may include a substantially parallel thread which may include a longitudinal axis which is substantially parallel to a longitudinal axis of the respective tubular member. This provides the advantage that the attachment means has a minimized radial extent which means that the inner bore of the connection members is substantially unrestricted at the location of the connection members. Optionally in alternative embodiments, the thread provided on the male and female members may comprise a linearly tapered thread which is at an angle to the central longitudinal axis of the respective tubular member, where the thread angle may be arranged with one end of the thread radially closer to the central longitudinal axis of the connecting members than the other end of the thread.

The primary surface of the female member may be located radially outwardly of the secondary surface; the secondary surface of the female member is located closer to the central longitudinal axis of the female connecting member than the primary surface.

The primary surface of the male member may be located radially outwardly of the secondary surface; the secondary surface of the male member is located closer to the central longitudinal axis of the male connecting member than the primary surface.

The respective attachment means of the male and female members may be located in between the respective primary and secondary surfaces.

The primary surface of the female member may include a longitudinally outermost end of the female member and may be provided at an end of the female member which is longitudinally and radially outer of the female member attachment means. The secondary surface of the female member may be distal of the longitudinally outermost end of the female member and may be provided radially and longitudinally inner of the female member attachment means.

The secondary surface of the male member may include a longitudinally outermost end of the male member and may be provided at an end of the male member which is radially inner and longitudinally outer of the male member attachment means. The primary surface of the male member may be distal of the longitudinally outermost end of the male member and may be provided radially outer and longitudinally inner of the male member attachment means.

The primary surface of the male member may include an at least partially tapered end which may form a shoulder portion and which may comprise a tapered portion angled with respect to an axis perpendicular to the longitudinal axis of the male member. The said tapered portion of the male member primary surface shoulder portion may be angled, from radially innermost to outermost, in the direction toward the rest of the male connecting member and which may be angled, from radially innermost to outermost, in the direction toward the male member attachment means. The said tapered angle may be in the region of 1 degree to 45 degrees, e.g., in the region of 10 to 20 degrees.

The primary surface of the female member may include a female shoulder portion and which may comprise a tapered portion angled with respect to an axis perpendicular to the longitudinal axis of the female member. The tapered portion of the female member primary surface shoulder portion may be angled, from radially innermost to outermost, in the direction toward the rest of the female connecting member and which may be angled, from radially innermost to outermost, in the direction toward the female member attachment means, perhaps by a substantially similar angle as that of the tapered portion of the male member primary surface shoulder portion such that the female member, and moreover, the longitudinally outermost end of the female member may be substantially prevented from moving radially outward when connected to the male member.

The secondary surface of the male member may include an at least partially tapered end which may form a shoulder portion and which may comprise a tapered portion angled with respect to an axis perpendicular to the longitudinal axis of the male member. The tapered portion of the male member secondary surface shoulder portion may be angled, from radially innermost to outermost, away from the rest of the male connecting member and which may be angled, from radially innermost to outermost, away from the male member attachment means. The said tapered angle may be in the region of 1 degree to 45 degrees, e.g., in the region of 10 to 20 degrees.

The secondary surface of the female member may include a female shoulder portion and which may comprise a tapered portion angled with respect to an axis perpendicular to the longitudinal axis of the female member. The said tapered portion of the female member secondary surface shoulder portion may be angled, from radially innermost to outermost, away from the rest of the female connecting member and which may be angled, from radially innermost to outermost, away from the female member attachment means, perhaps by a substantially similar angle as that of the tapered portion of the male member such that the male member, and moreover, the longitudinally outermost end of the male member may be substantially prevented from moving radially inward when connected to the female member.

The primary and secondary surfaces of the male and female connecting members may include support means which may further comprise a support platform or ledge adapted to support the respective longitudinally outermost ends of the male and female members when the connection means is engaged such that the male member is substantially prevented from moving radially outward and the female member may be substantially prevented from moving radially inward. The support means may be provided in the form of a surface, which may be a platform or ledge and which may be arranged to lie on an axis substantially parallel or co-axial to the longitudinal axis of the respective male and female connecting members.

The support means of the primary surface of the male member may be arranged radially inwardly of and longitudinally outwardly of the male member primary surface tapered portion and is further arranged radially outwardly of and longitudinally inwardly of the male member attachment means. The support means of the secondary surface of the male member may be arranged radially outwardly of and longitudinally inwardly of the male member secondary surface tapered portion and is further arranged radially inwardly of and longitudinally outwardly of the male member attachment means.

The support means of the primary surface of the female member may be arranged radially inwardly of and longitudinally inwardly of the female member primary surface tapered portion and is further arranged radially outwardly of and longitudinally outwardly of the female member attachment means. The support means of the secondary surface of the female member may be arranged radially outwardly of and longitudinally outwardly of the female member secondary surface tapered portion and is further arranged radially inwardly of and longitudinally inwardly of the female member attachment means.

The combined effect of the support means and tapered surfaces has the advantage that they substantially prevent movement (such as buckling when the connection means is being made up to high levels of torque) of the male and female connection members in the radial direction.

Optionally, the male connection member may be provided on one end of a body member and the female member provided on the other thereby creating a double shouldered connection which is capable of remaining engaged when a high torque is applied to it. Alternatively, one of a male or female member may be provided on one end of the member only, or in a further alternative, either a male or female member may be provided on each end of the body member.

The substantially tubular members may be members which are included in or make-up a drill string and may be members provided on or in a drilling jar, impact enhancing tool, drill pipe, flow circulation tool, shock tools, thrusters and bumper subs or other suitable tools such as any suitable Bottom Hole Assembly (BHA) tools.

These and other features, aspects, and advantages of the present invention will become more apparent from the following description, appended claims, and accompanying exemplary embodiments shown in the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a cross-sectional view of an upper third of an impact enhancer apparatus in accordance with a first embodiment of the present invention;

FIG. **1**B is a cross-sectional view of a middle third of the impact enhancer apparatus in accordance with the first embodiment of the present invention;

FIG. **1**C is a cross-sectional view of a lower third of the impact enhancer apparatus in accordance with the first embodiment of the present invention;

FIG. **2**A is a cross-sectional view of a female end connector utilized in the impact enhancer apparatus of FIGS. **1**A-**1**C, which female end connector is in accordance with a second embodiment of the present invention;

FIG. **2**B is a further cross-sectional view of the female end connector of FIG. **2**A in accordance with the second embodiment of the present invention;

FIG. **2**C is a detailed view of an internal screw thread of the female end connector of FIGS. **2**A and **2**B;

FIG. **3**A is a cross-sectional view of a male end connector to be used in conjunction with the female end connector of FIGS. **2**A-**2**C in accordance with the second embodiment of the present invention;

FIG. **3**B is a further cross-sectional view of a male end connector to be used in conjunction with the female end connector of FIGS. **2**A-**2**C in accordance with the second embodiment of the present invention;

FIG. **3**C is a detailed view of an external screw thread of the male connector of FIGS. **3**A and **3**B; and

FIG. **4** is a detailed schematic diagram of a parallel threaded shoulder joint in accordance with the second embodiment of the present invention.

DETAILED DESCRIPTION

Embodiments of the invention are illustrated in the drawings. An effort has been made to use the same, or like, reference numbers throughout the drawings to refer to the same or like parts.

When viewed in conjunction (as indicated by the connecting arrows) with one another, FIGS. **1**A-**1**C show an impact enhancer apparatus in accordance with a first embodiment of the present invention.

The impact enhancer apparatus shown in FIGS. **1**A-**1**C comprises an internal member or mandrel **10** surrounded by an external member or housing **12**. The internal mandrel **10** is arranged such that it may move axially with respect to the outer housing **12**.

The internal mandrel **10** is a substantially tubular member that spans the majority of the length from the upper to the lower end of the impact enhancer apparatus. The internal mandrel **10** comprises an uppermost connecting mandrel **14**, which is connected at its lower end to an upper abutment mandrel **16**. The upper abutment mandrel **16** is connected to a lower abutment mandrel **18**. Finally, the lower abutment mandrel **18** is connected to a lowermost end mandrel **20**.

The external housing **12** comprises an uppermost seal housing **22**, which is connected to an upper abutment housing **24**. The upper abutment housing **24** is connected to a lower abutment housing **26** (lock housing **26**). Finally, the lower abutment housing **26** is connected to a lowermost connecting housing **28**. It should be noted that the uppermost seal housing **22** is connected to the upper abutment housing **24** via a double shouldered spline **32**, which will be described in more detail subsequently. Also, in this embodiment, each of the joints J**1**, J**2** and J**3** comprises corresponding threaded sections that are substantially parallel to the longitudinal axis L of the impact enhancer apparatus.

The uppermost connecting mandrel **14** of the internal mandrel **10** has a box section **34** provided with a standard tapered thread portion **36** that allows connection to a pin section of the lower end of an upper portion of a drill string (not shown). The box section **34** decreases in diameter to allow the connecting mandrel **14** to enter the external housing **12**. Such box sections **34** are common in the industry and suitable box sections include the HT-50 and XT56 connections provided by Grant and Prideco and the WT-58 provided by Hydril. The mandrel **14** continues along the internal bore of the housing **12** until it reaches an indented portion **38** that comprises an arrangement of longitudinally extending and circumferentially spaced grooves that telescopically engage with internally projecting splines mounted on the spline **32**, to prevent rotation from occurring between the internal mandrel **10** and external housing **12**. At the lower portion of the connecting mandrel **14**, a double headed hammer (or "stop") **40** is attached to the outer circumference of the mandrel **14**. The hammer **40** comprises a collar, which has upper **42** and lower **44** stroke limiting surfaces that act to prevent overstressing of the springs as will be described subsequently.

With respect to FIG. **1**B, the upper abutment mandrel **16** has a shoulder **30** formed around the circumference of the mandrel **16**. The lower abutment mandrel **18** is provided with a female end socket **242** which creates upper **244** and lower **46** shoulders.

Resilient means or energy storage means, which include an upper compression spring stack **48** and a lower compression spring stack **50**, are provided in the annulus created between the inner mandrel **10** and the external housing **12**. A cylindrical spacer collar **52** is provided between the upper **48** and lower **50** stacks. The stacks **48**, **50** are held within the annulus by a force that can be varied by screwing an adjuster **72** (which is coupled to the internal mandrel **10** by screw threads) either in or out, to increase or decrease (as desired) the initial compression force acting on the stacks **48**, **50**.

The secondary (upper) spring stack **48** comprises a hard spring and in the specific example given herein comprises a number of disk springs (such as Belleville springs) stacked adjacent each other. Each disk spring **48** comprises a toroid made from a suitable material, e.g., hardened steel, which has been pressed into a dish shape during manufacture. When a load is exerted on each disk spring **48**, it will tend to flatten out of the disk shape imparted on it during manufacture. In this embodiment, the upper spring stack **48** comprises disks that alternate between four consecutive disks, which have their dish camber in one direction, and four consecutive disks, which have their dish camber in the opposite direction.

The lower spring stack **50** also comprises a number of disk springs **50** stacked adjacent each other. However, the lower spring stack **50** includes disks that alternate between two consecutive spring disks, which have their dish camber in one direction, and two consecutive disks, which have their dish camber in the opposite direction. The purpose of the differing spring orientation between the upper and lower stacks **48**, **50** will be described subsequently.

The end mandrel **20** (shown in FIG. **1**C) creates a chamber **74** between the end mandrel **20** outer circumference and the external housing **12**. The end mandrel **20** also provides additional weight, which enhances the acceleration produced by the impact enhancer apparatus, to increase impact force generated by a drilling jar also located in the drill string.

The uppermost seal housing **22** of the external housing **12** provides a fluid chamber **75** that is provided with a moveable balance piston **78** and a seal **80**. A fluid port **76**, which is open to the surrounding bore, is also provided through the wall of the uppermost seal housing **22**. A plug **82** is provided on the seal housing **22** to obturate another part but which is located below the balance piston **78**, such that hydraulic fluid can be inserted into the annulus between the external housing **12** and internal mandrel **10**. This arrangement prevents any pressure differential from building-up across the wall of the apparatus, as any relative increase in pressure below the piston **78** will be compensated by the piston **78** moving upwardly and any relative decrease in pressure below the piston **78** will be compensated by the piston **78** moving downward. This has the advantage of preventing the build-up of a pressure differential (which may damage or otherwise adversely affect operation of the tool) across the wall of the apparatus, while preventing hydraulic fluid in the apparatus from mixing with the oil/other material surrounding the apparatus.

The upper abutment housing **24** is provided with an internal shoulder **84** that is positioned such that it provides an impact surface against which the lower impact surface **44** of the stop **40** may come to rest. A shoulder **102** is provided on the spline **32** to provide an impact surface against which the upper impact surface **42** of the stop **40** may come to rest, as will be described in more detail subsequently.

The lower abutment housing **26** comprises a substantially tubular member that has a constant inner circumference within which the compression stacks **48**, **50** are located.

A lower seal housing **29** provides the fluid chamber **74**, which has a moveable balance piston **94**. The lower seal housing **29** arrangement prevents any pressure differential from building-up across the wall of apparatus by providing a similar compensation system to that previously described for the upper seal housing **22**.

The lowermost connecting housing **28** has a pin section **98** provided with a standard tapered thread portion **100** that allows connection to a standard box section of the upper end of a lower portion of the drill string (not shown).

It should be noted that a series of inwardly protruding shoulders **102**, **104**, **106** and **108** are created by the connections between each of the components making-up the external housing **12**. Outwardly projecting shoulder **54** is also created on the internal mandrel **10** by the connection between lower abutment mandrel **18** and lowermost end mandrel **20** of the internal mandrel **10**.

With reference to FIGS. **2**A-**2**C, **3**A-**3**C and **4**, one embodiment of a connection means in accordance with a second embodiment of the present invention will now be described. In this embodiment, the connection means is incorporated into the impact enhancer apparatus (i.e., the mandrel **10** and housing **12**) of FIGS. **1**A-**1**C. The connection means includes an inner or male pin **114**, which, when connected, resides within an outer or female box **116**. A threaded portion **118** is provided on the outer circumference of the pin **114** and is formed such that it co-operates with a corresponding threaded portion **120** formed on the inner circumference of the box **116**. As shown in FIGS. **2**C and **3**C, the threaded portions **118**, **120** may include a V-shaped profile but could, in alternative embodiments, include square, buttress, trapezoidal or acme type threads.

The threaded portions **118** and **120** are at or near parallel with the longitudinal axis L of the apparatus upon which the connection means is provided and, therefore, are referred to as parallel threads (as opposed to tapered threads commonly used, for instance, in drill pipe connections). The pin **114** has a shallow V-shaped or gull winged shaped indentation on its longitudinally outermost end face (i.e., the leftmost portion of the pin shown in FIG. **4**). The indentation, which comprises a tapered wall **122** and a flat wall **124** (as shown in FIG. **4**), will provide a secondary shoulder surface as will be described subsequently. The tapered wall **122** is angled with respect an axis that is perpendicular to the longitudinal axis L of the male pin **114**. As shown in FIG. **4**, the tapered wall **122** is angled at approximately 15 degrees (from radially innermost to outermost) away from the rest of the pin **114** (i.e., the rest of the pin **114** to the right of the flat wall **124**) and, therefore, is angled (from radially innermost to outermost) away from the parallel thread **118**.

Pin **114** also has a box receiving shoulder **128** that is distal of the tapered wall **122** and that is located radially outer and longitudinally inner of the thread **118**, where the shoulder **128** will provide a primary shoulder surface as will be described subsequently. The shoulder **128** is angled with respect the axis that is perpendicular to the longitudinal axis L of the male pin **114**. Specifically, the shoulder **128** is angled at approximately 15 degrees (from radially innermost to outermost) toward the rest of the pin **114** (i.e., the rest of the pin **114** to the left of the shoulder **128**) and, therefore, is angled (from radially innermost to outermost) toward the parallel thread **118**. Accordingly, the thread **118** is located radially and longitudinally between the shoulder **128** and the tapered wall **122**.

The outer box **116** has a single tapered face **126** that provides a primary shoulder surface and that is angled with respect to the axis that is perpendicular to the longitudinal axis L of the outer female box **116**. Specifically, the tapered face **126** is angled at approximately 15 degrees (from radially innermost to outermost) toward the rest of the outer female box **116** (i.e., the rest of the box **116** to the left of the tapered face **126**) and, therefore, is angled (from radially innermost to outermost) toward the parallel thread **120** at substantially the same angle as that of the box receiving shoulder **128**. The outer box **116** also has tapered pin receiving shoulder **130**, which is distal of the tapered face **126**, which is located radially and longitudinally inner of the female thread **120**, and which will provide a secondary shoulder surface. As shown in FIG. **4**, the pin receiving shoulder **130** is angled at approximately 15 degrees (from radially innermost to outermost) away from the rest of the box **116** (i.e., the rest of the box **116** to the right of the pin receiving shoulder **130**) and, therefore, is angled (from radially innermost to outermost) away from the parallel thread **120**. Thus, the tapered pin receiving shoulder **130** is provided with a substantially similar taper angle as that of tapered wall **122**. Accordingly, the thread **120** is located radially and longitudinally between the tapered face **126** and the tapered pin receiving shoulder **130**.

It should be noted that box **116** is at least equal to, and may be slightly longer than the length of inner pin **114** as will be discussed subsequently.

As shown in FIG. **1**A, the connection means may be provided on both ends of a double shouldered spline **32**. Each double shouldered spline **32** comprises a pin **114** and box section **116** that respectively connect, in accordance with the first embodiment of the present invention, to a box and pin section of another component of the apparatus upon which the spline **32** is installed.

With respect to FIG. **4**, the pin **114** is screwed into the box section **116** when the impact enhancing tool is assembled; the threads **120** and **118** cooperate to cause tapered face **126** of the box **116** to abut against box receiving shoulder **128**, thereby providing a primary (external of the thread) shoulder junction. This creates a metal to metal seal between the tapered face **126** and the shoulder **128** and also provides a primary shoulder between the pin **114** and box **116** into which torque can be delivered and stored.

Tapered wall **122** also abuts against pin receiving shoulder **130**, thereby creating a secondary (internal of the thread) metal to metal seal between the tapered face **126** and the shoulder **128**. The abutment of tapered wall **122** and should **130** also provides a secondary shoulder joint between the pin **114** and box **116** into which torque can be delivered and stored. However, as discussed previously, the length of box **116** is manufactured such that it is at least equal to that of pin **114**, and may be slightly longer (e.g., about 0.15 mm) than the length of pin **114**. This ensures that the seal created between face **126** and shoulder **128** is made before the seal between wall **122** and shoulder **130**. Therefore, the seal between face **126** and shoulder **128** is regarded as the primary shoulder joint and the internal seal between the wall **122** and shoulder **130** is regarded as the secondary shoulder joint.

When the impact enhancing tool is located in a drill string along with a drilling jar and the drill string is compressed when, for example, downward jarring is required (or tensioned when, for example, upward jarring is required) pin **114** is prevented from splaying inwardly toward the longitudinal axis L of the apparatus upon which the connection means is provided due to the abutment between the tapers on wall **122** and shoulder **130**. The pin **114** is also prevented from diving outwardly (away from the longitudinal axis L) due to a support means in the form of support ledge **140** on the box section **116**, where the support ledge **140** is arranged to lie on an axis substantially parallel and co-axial to the longitudinal axis L of the female box section **116**. As shown in FIG. **4**, the support ledge **140** is arranged radially outwardly of and longitudinally outwardly of the pin receiving shoulder **130** and is, therefore, located radially inwardly of and longitudinally inwardly of the female thread **120**.

Box section **116** is prevented from splaying outwardly away from the longitudinal axis L of the apparatus due to the taper on wall **126** and shoulder **128**. The box **116** is also prevented from diving inwardly (toward longitudinal axis L) due to a support ledge **142** on the pin section **114**. As shown in FIG. **4**, the support ledge **142** is arranged radially inwardly of and longitudinally outwardly of the male shoulder **128** and is, therefore, located radially outwardly of and longitudinally inwardly of the male thread **118**.

This provides a very secure joint that will withstand very high torsional forces, without the pin **114** or box **116** sections splaying or diving inwardly/outwardly, as the combined effect of the support ledges **140**, **142** and tapered surfaces **122/130**, **126/128** substantially prevents movement of the male pin **114** and female box **116** in the radial direction. The joint created by the connection means also discourages unintentional backing off (i.e., unscrewing) of the components of the apparatus upon which the connection means is provided since a large rotational force would be required in order to overcome the friction between the primary or external shoulder joint **126/128** (face **126** and wall **128**) and secondary or internal shoulder joint **122/130** (face **122** and wall **130**), once the desired make-up torque has been applied to the connection.

The parallel arrangement of threaded portions **118** and **120** allow a secure connection to be created between two tubular members, while using a minimal amount of borehole space/radial distance. In other words, the joints do not encroach on the internal bore more than absolutely necessary, as no taper is required on the threaded portions **118** and **120**.

In addition, the connection means prevents over stretching of the pin **114** and box **116** sections (which often occurs in standard tapered thread pin and box joints) from occurring both during connection of the tubular members and during operation of the drill string. Any tendency for the pin **114** or box **116** to over stretch is avoided by the inability of the pin **114** and box **116** to increase in length due to the respective shoulders **122/130** and **126/128**. Accordingly, the connection means permit a much higher level of torque to be applied to itself when screwing the connections together as compared to conventional connections which is particularly useful in extended reach/horizontal wells.

The connection means is not limited to use on the spline **32** and indeed the impact enhancing apparatus shown in FIGS. **1A-1C** is provided with further joints **J1**, **J2**, **J3** and **J4**, each of which has: (a) a similarly tapered arrangement; and (b) threaded portions that are substantially parallel to the longitudinal axis L of the impact enhancing apparatus. Furthermore, the connection means is not limited to use on an impact enhancing apparatus and indeed it may be used on virtually any tool or tubular in which a high torque connection between tubular members may be required, e.g., drilling jar, accelerators, drill pipe, flow circulation tools, shock tools, thrusters, and bumper subs, etc. and any other suitable BHA tools.

In operation, the impact enhancer apparatus is installed in the drill string prior to inserting the drill string downhole, and is normally installed above a drilling jar (not shown). In the event that the drill string becomes stuck downhole (due to, for example, the drill bit becoming lodged in the formation being drilled) the impact enhancer helps free the drill string by increasing the jarring force exerted by the jar apparatus.

Depending upon the nature of the jam between the drill string and the formation, the operator may chose to jar the drill string in the upward or the downward direction, or by alternating between both directions. When jarring the drill string in the upward direction, it is desirable that the impact enhancer be capable of storing a large amount of energy since drill strings are inherently able to withstand high tensile forces. However, when jarring the drill string in the downward direction, it is desirable that a smaller amount of energy be stored in the impact enhancer apparatus, as drill strings are inherently less able to withstand high compressive forces. Although conventional double acting impact have this capability, such conventional impact enhancers undesirably require complete compression of the resilient means when the high compressive force is exerted on the drill string, which is likely to result in buckling of the drill string.

When jarring the drill string in the upward direction, the upper portion of the drill string is pulled upwardly by the operator via the drilling rig (not shown). This exerts an upward force on the internal mandrel **10** with respect to the external housing **12** (which is prevented from moving upwardly due to the stuck drill bit (not shown)). The upward movement of the internal mandrel **10** causes outwardly projecting shoulder **54** on lowermost end mandrel **20** to abut against adjuster **72**, which causes the lower spring stack **50** to be forced against spacer collar **52**. Spacer collar **52**, in turn, pushes upper spring stack **48** against inwardly protruding shoulder **104** on the external housing **12**. The skilled reader will, therefore, note that at this point both the upper **48** and lower **50** spring stacks are being compressed as the inner mandrel **10** moves upwardly, and thus storage of energy is built-up within both upper **48** and lower **50** spring stacks. However, the arrangement of the disk springs on the lower spring stack **50** allows the upper spring stack **48** to be compressed more easily than the lower spring stack **50** and, therefore, the upper spring stack **48** will tend to compress far more under pressure than the lower spring stack **50** at this point.

With respect to FIGS. **1A-1C**, the arrangement of the spring stacks **48** and **50** will now be described. The upper spring stack **48** comprises paired sets disks. Each set of disks comprises four disks that arranged adjacent each other in parallel. For illustrative purposes only, if the maximum compression allowable by each disk set is say 10 mm, then the total compression distance available by completely flattening all eights disks in a paired set of disks is 20 mm. However, if the disks are arranged in sets of two parallel disks, as the case in the lower spring stack **50**, the total compression distance available by completely flattening four disks (i.e., two sets of two disks in parallel) is 20 mm but only requires half the compression force. Therefore, when the primary stack **50** is compressed by a force F, the resulting compression displacement will be the same as the secondary stack under twice the force F.

While each spring stack **48**, **50** is being compressed, the lower shoulder **46** on the female socket **242** of the lower abutment mandrel **18** gradually moves away from the lower spring stack **50** and toward the upper spring stack **48**. When the upper shoulder **244** meets the upper stack **48**, further compression of the lower stack **50** is avoided. Further compression is avoided because further upward movement of the internal mandrel **10** allows the spacer collar **52** to move upward, as the lower end of the upper spring stack **48** is now forced upward, and is supported by, surface shoulder **244** of the female end socket **242**. Thus, continued upward movement of the internal mandrel **10** results in continued compression of the upper spring stack **48** but no further compression of the lower spring stack **50**. This is advantageous because total compression of the disk springs of the lower spring stack **50** is avoided. As will be understood by the skilled reader, pulling against the large resilient force provided by the stacks **48**, **50** requires very large forces to be exerted on internal mandrel **10**. This force is provided by pulling upon the internal mandrel **10** via the drill string using the drill rig (not shown).

When the jar apparatus (not shown) located in line with the present impact enhancer apparatus is fired in the upward direction, the energy stored within the upper and lower stacks **48** and **50** is released due to the disk springs wishing to return to their relaxed configuration, as shown in FIGS. **1A-1C**. This release of energy will act on the inner mandrel **10** to provide a large acceleration force on the external housing **12**, which accelerates the inner mandrel of the jar apparatus, thereby causing a far greater impact to occur between the hammer and anvil (or other) on the jar apparatus. In this regard, it should be noted that the outer housing **12** of the impact enhancer is connected to the inner mandrel of the jar apparatus.

When jarring the drill string in the downward direction, the upper portion of the drill string is effectively pushed downwardly by the operator via the drilling rig (not shown) by letting off weight at the drilling rig. This exerts a downward force on the internal mandrel **10** with respect to the external housing **12** (which is prevented from moving downwardly due to the stuck drill bit (not shown)). The downward movement of the internal mandrel **10** causes lower shoulder **46** on the female end socket **242** to compress lower spring stack **50** against the adjuster **72**; the adjuster **72** is prevented from moving any further down the apparatus due to inwardly projecting shoulder **106** on the external housing **12**. The upper spring stack **48** is not compressed by downward movement of the inner mandrel **10**, as the lower spring stack is compressed by shoulder **46**. Therefore, the upper spring stack **48** simply moves along with shoulders **30**, **46** and spacer collar **52**, without being compressed therebetween.

When the jar apparatus (not shown) located in line with the present impact enhancer apparatus is fired in the downward direction, only the resilient force from the energy stored in the lower stack **50** acts on the external housing **12**. The energy stored in the lower stack **50**, which acts on the external housing **12**, provides an acceleration force on the external housing **12** that accelerates the inner mandrel of the jar apparatus, thereby causing a far greater impact to occur between the hammer and anvil (or other) on the jar apparatus.

It should be noted that the double headed hammer **40** acts in conjunction with shoulders **84** and **102** to act as stroke limiters that prevent over stressing of spring stacks **48** and **50**.

The stroke length of the impact enhancer apparatus is designed such that it is less than the stroke length of the jar apparatus with which it is used. This ensures that the impact enhancer imparts all of its acceleration force upon the hammer (not shown) of the jar apparatus before the jarring impact occurs.

Although the aforementioned describes embodiments of the invention, the invention is not so restricted. For instance, the parallel threads **118**, **120** could in certain circumstances, be replaced by linearly tapering threads if, for instance, increasing the radial extent of the connection was acceptable in a given downhole tool or other tubular member. It should also be noted that the outer circumference of the tubular members, which were described herein as being circular in cross-section, need not be so. Rather, the outer circumference of the tubular members could have other cross-section such, e.g., square, hexagonal, etc.; such alternate cross-sections may be particularly applicable in the areas in between the connection means.

It light of the foregoing, it will be apparent to those skilled in the art that various modifications and variations can be made to the disclosed embodiments of the present invention without departing from the scope or spirit of the invention. Accordingly, these other apparatuses and methods are fully within the scope of the claimed invention. Therefore, it should be understood that the apparatuses and methods described herein are illustrative only and are not limiting upon the scope of the invention, which is indicated by the following claims.

What is claimed is:

1. An impact enhancer apparatus comprising:
- a substantially tubular inner member;
- a substantially tubular outer member which is axially movable in relation to the inner member; and
- a primary energy storage device adapted to store enemy when the inner member is moved in either of upward and downward axial directions with respect to the outer member; and
- a secondary energy storage device adapted to store energy when the inner member is moved in the upward axial direction with respect to the outer member;
- wherein the primary and secondary energy storage device are adapted to resist movement of the inner member in the upward axial direction with respect to the outer member with a larger resistive force than when the primary energy storage device resists movement of the inner member in the downward axial direction with respect to the outer member.

2. An impact enhancer apparatus according to claim **1**, wherein the primary energy storage device comprises a primary biasing device.

3. An impact enhancer apparatus according to claim **2**, wherein the primary biasing device is any one of a spring device selected from the group consisting of: disk springs; coiled springs; fluid and gas springs.

4. An impact enhancer apparatus according to claim **1**, wherein the secondary energy storage device comprises a secondary biasing device.

5. An impact enhancer apparatus according to claim **4**, wherein the secondary biasing device is any one of a spring device selected from the group consisting of: disk springs; coiled springs; fluid and gas springs.

6. An impact enhancer apparatus according to claim **1**, wherein the primary energy storage device is adapted to store energy when compressed by movement of the inner member in either of the first and second axial directions with respect to the outer member.

7. An impact enhancer apparatus according to claim **1**, wherein the secondary energy storage device is adapted to store energy when compressed by movement of the inner member in the first axial direction with respect to the outer member.

8. An impact enhancer apparatus according to claim **1**, wherein the primary energy storage device is adapted to resist upward movement of the inner member with respect to the outer member by a first resilient force when the inner member is displaced to an upward displacement boundary.

9. An impact enhancer apparatus according to claim **8**, wherein the secondary energy storage device is adapted to resist upward movement of the inner member with respect to the outer member by a second resilient force when the inner member is displaced past the upward displacement boundary.

10. An impact enhancer apparatus comprising:

a substantially tubular inner member;

a substantially tubular outer member which is axially movable in relation to the inner member; and

a primary energy storage device adapted to store energy when the inner member is moved in either of upward and downward axial directions with respect to the outer member; and

a secondary energy storage device adapted to store energy when the inner member is moved in the upward axial direction with respect to the outer member;

wherein the primary energy storage device is adapted to provide a lower level of resistive force to compression than that provided by the secondary energy storage device.

11. An impact enhancer apparatus according to claim **10**, wherein the difference in the level of resistive force provided by the energy storage device is determined due to the orientation of the energy storage device which selectively results in a greater or lesser compression displacement when substantially the same force is placed upon the energy storage device.

12. An impact enhancer apparatus comprising:

a substantially tubular inner member;

a substantially tubular outer member which is axially movable in relation to the inner member; and

a primary energy storage device adapted to store energy when the inner member is moved in either of upward and downward axial directions with respect to the outer member; and

a secondary energy storage device adapted to store energy when the inner member is moved in the upward axial direction with respect to the outer member;

wherein the primary energy storage device comprises a plurality of spring disks oriented in the same direction as one another;

wherein the plurality of disks in the primary energy storage device are arranged with a number of disks oriented in one direction alternating with a number of disks oriented in the other direction.

13. An impact enhancer apparatus according to claim **12**, wherein the secondary energy storage device comprises a plurality of spring disks oriented in the same direction as one another.

14. An impact enhancer apparatus according to claim **13**, wherein the plurality of disks in the secondary energy storage device are arranged with a greater number of disks of the primary energy storage device oriented in one direction alternating with the same greater number of spring disks oriented in the other direction.

15. An impact enhancer apparatus comprising:

a substantially tubular inner member;

a substantially tubular outer member which is axially movable in relation to the inner member; and

a primary energy storage device adapted to store energy when the inner member is moved in either of upward and downward axial directions with respect to the outer member; and

a secondary energy storage device adapted to store energy when the inner member is moved in the upward axial direction with respect to the outer member;

wherein the primary and secondary energy storage devices are located in a respective annulus formed between the inner and outer members;

wherein the primary energy storage device is further located between a second arrangement of upper and lower shoulders formed on the inner member and a lower shoulder formed on the outer member and a lower shoulder formed on a moveable member;

wherein the secondary energy storage device is further located between a first arrangement of upper and lower shoulders formed on the inner member and an upper shoulder formed on the outer member and an upper shoulder formed on a moveable member;

wherein the moveable member is located in the annulus located between the primary and secondary energy storage devices; and

wherein the moveable member comprises a greater axial extent and thus a greater distance between its upper and lower shoulders than the distance between the inner member lower shoulder of the first arrangement and the inner member upper shoulder of the second arrangement.

16. An impact enhancer apparatus according to claim **15**, wherein the impact enhancing apparatus is arranged such that, in the absence of compression to the energy storage device, the distance between the upper shoulder of the first arrangement and the upper shoulder of the second arrangement substantially equals the distance between the upper shoulder of the outer member and the lower shoulder of the moveable member.

17. A method of increasing the jarring force imparted by a jar apparatus comprising:

providing a substantially tubular inner member;

providing a substantially tubular outer member;

providing an energy storage device capable of storing greater energy therein due to upward movement of the inner member with respect to the outer member;

wherein the energy storage device comprises a primary and a secondary energy storage device;

moving the inner member in the upward direction to thereby cause the primary and secondary energy storage device to be compressed;

including moving the inner member in the downward direction and moving the secondary energy storage device with the inner member to thereby cause only the primary energy storage device to be compressed.

18. A method according to claim **17**, including providing an upward displacement limit so that on reaching the upward displacement limit, further upward movement of the inner member causes the secondary energy storage device to be compressed further.

19. An impact enhancer apparatus comprising:

a substantially tubular inner member;

a substantially tubular outer member which is axially movable in relation to the inner member; and

a compressible primary energy storage device comprising a level of resistive force to compression and in which energy is stored due to compression thereof when the inner member is moved in either of first and second axial directions with respect to the outer member;

a compressible secondary energy storage device comprising a level of resistive force to compression and in which energy is stored due to compression thereof but only when the inner member is moved in the first axial direction with respect to the outer member;

wherein the apparatus permits more energy to be stored, in both the primary and secondary energy storage devices, when the inner member is moved in the first axial direction over a certain distance with respect to the outer member compared with the amount of energy permitted to be stored in the primary energy storage device when the inner member is moved in the second axial direction over the same distance.

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